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Modeling Risk Categories to Predict the Longitudinal Prevalence of Childhood Diarrhea in Indonesia

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Abstract. We present an innovative approach for analyzing diarrheal prevalence data that uses latent variables to model the relationships between multiple, interdependent environmental risk factors, and socioeconomic mediators. This strategy was applied to elucidate diarrheal longitudinal prevalence risk factors in children 1–4 years of age in low-income areas of Jakarta, Indonesia. Through a prospective cohort study, we identified 257 children who had at least one episode of diarrhea. At the onset of the study, we collected responses to 44 indicators, covering a wide range of previously identified diarrhea risk factors, including demographic and socioeconomic factors. We used exploratory factor analysis to uncover four latent categories of risk factors and their respective indicators from the initial pool of 44 indicators. Thereafter, we used structural equation modeling to model the relationships between the four risk categories and diarrheal longitudinal prevalence, controlling for socioeconomic and demographic covariates. Our final model elucidated several pathways to longitudinal diarrheal prevalence. Most notably, poverty exerts its effect on increased diarrheal prevalence via dual pathways: poor household hygiene and food quality, controlling for covariates. Implications of this and other findings for disease control in Jakarta are discussed.

INTRODUCTION

Diarrhea continues to be a leading cause of early childhood mortality and morbidity in lesser developed nations and is responsible for nearly one million deaths annually.[1] In Indonesia, diarrhea is a leading cause of healthcare expenditures[2] and mortality[3] among infants. Most acute diarrheal episodes can be effectively treated with oral rehydration therapy. Conversely, persistent and prolonged diarrhea is more difficult to manage[4] because of a vicious cycle of malnutrition, reduced immunity, and prolonged or repeated disease.[5–8] Persistent and prolonged diarrhea causes numerous developmental impacts, including long-term cognitive deficits.[9] Numerous studies have identified individual risk-factors for diarrheal disease incidence among children in developing countries, but few have investigated factors associated with the longitudinal prevalence,[10] rather than the incidence of infections.[4]

Gastrointestinal disease can be transmitted by a number of interdependent environmental factors, which are in turn influenced by socioeconomic factors.[4,11] Water and sanitation risk factors, including inconsistent hand washing,[12,13] access to sanitation,[14] and access to clean drinking water,[15–20] have been characterized, in addition to socioeconomic and age-related risk factors.[4,21–23] Infectious agents for diarrhea differ by transmission route, with different associated disease characteristics likely associated with differing risk-factors and transmission routes.

Previous analyses of environmental risk factors for diarrhea are most often based on statistical inference using a variety of regression models. Most studies identify individual risk factors for diarrhea.[12,14,15,24,25] However, there is heterogeneity across and within studies with regard to the relative risk associated with various exposure routes, within different environments, possibly reflecting the relative contribution of environmental exposure routes for different pathogens that may cause diarrhea. Practitioners have promoted interventions such as water, sanitation and hygiene improvements to reduce risk of exposure via all routes,[15,26,27] but there is little epidemiologic evidence of their benefits. A hierarchical-effect decomposition strategy that groups risk factors into discrete blocks[23,28,29] has been introduced to improve analyses by enabling investigators to understand direct and indirect effects. However, because the methods used for this strategy rely only on measurable risk factors, it is not able to measure direct relationships among abstract variables that are difficult to measure or quantify, nor is it able to analyze complex relationships among covariates and these variables.

Structural equation modeling (SEM) is a more general version of generalized linear modeling that is able to incorporate various types of data.[30,31] Regression methods are limited because they can model individual risk factors but not categories of risk. For example, to understand the relative importance of a large number of hypothesized risk factors of diarrheal prevalence, regression models would need to individually incorporate all hypothesized risk factors. Backward/forward selection strategies are thus typically used to identify individual risk factors that are significant. Often, several risk factors are concurrently significant, making it difficult to quantitatively compare various risk factors within the same study area or design.

In this report, we present an innovation in data analysis for water, sanitation, hygiene, and diarrhea studies. We propose a structural equation model to interpret environmental, socioeconomic, and health data collected form a child-cohort. This method is used to analyze childhood diarrhea prevalence in low-income areas of Jakarta, Indonesia.

METHODS

Study design and population. A prospective cohort study was conducted in two low-income areas of Jakarta, Indonesia (Tanjung Priok and Koja in north Jakarta and Pejaten Timur in south Jakarta). One thousand children 1–4 years of age were enrolled in the study. Participant selection and data collection are described elsewhere.[19] In brief, study participants were

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selected from among all age-eligible children registered at public child health centers (Posyandu). Data were collected from children via two methods. A baseline interview was conducted during participant enrollment (February 2011) and recorded directly into a Google Chrome™ survey program onto netbooks to minimize data entry errors. Questions were modeled on those previously validated for use in an economic survey in Indonesia.[32] Additional questions were incorporated to account for commonly discussed diarrheal risk factors.

A daily record of diarrhea was collected by using a Smiley diagram,[33,34] which primary caregivers were trained to complete during February–July 2011. Daily water use and boiling were monitored by using weekly logs in a similar way. Information contained within the survey sheets was verbally confirmed during collection. All surveys and diagrams were translated from English to Indonesian and back-translated by different certified translators. Any inconsistencies in translation were resolved by consensus. Methods were validated during a pilot survey (n = 100) conducted in Padang, Indonesia during December 2010. Data from log sheets were recorded daily to laptop computers and validated by field managers. A randomly selected 10% subset of the log sheets was further validated by separate data entry specialists.

The dependent variable was the longitudinal prevalence of diarrhea. Consistent with previous studies,[35–38] diarrhea was defined as having two or more loose stools or a loose stool containing blood or mucus in a given day. Longitudinal prevalence of diarrhea was calculated by dividing the total number of diarrhea-days (numerator) by the total number of days of follow-up per child (denominator). All rates are reported per 1,000 child-days.[28] To study longitudinal prevalence rather than incidence, we selected and analyzed data only for children who had at least one day of diarrhea.

We collected data on 44 risk factors that are deemed to be most important in Indonesia Table 1.[3,20,39–41] Specifically, we analyzed household hygiene, environmental quality, food hygiene, and water quality.[11,17,25,28] Covariates collected for analysis included whether the household, based on reported monthly income and household member number, did or did not fall below the official 2011 Indonesian poverty line (referred to as poverty status in the analytical section), child age, head of household education, and location within the city.

Analytic strategy. Our analytic strategy involves two stages: first, selection of risk categories and second, modeling the risk categories, covariates and longitudinal prevalence of diarrhea. The first uses exploratory factor analysis to select risk categories from 44 observed risk factors. Each risk category is represented by four respective risk factors with the highest factor loadings.[42] SPSS version 16.0.2 (IBM SPSS, Armonk, NY) was used to manipulate variables and perform the explanatory risk factor analysis.

The second stage elucidates the significant predictors of diarrhea longitudinal prevalence through SEM using AMOS version 18 (IBM, Armonk, NY).[43] Parameters in the SEM were estimated by the maximum-likelihood method, which compares the fit of a hypothesized structural model to the observed variance-covariance matrix. Traditionally, SEM researchers used Chi-square to test for model fitness. However, the exact fit hypothesis tested by chi-square is over-restrictive and sensitive to sample size and violations of normality.[42] A heuristic rule suggests that a model with a ratio of Chi-square to its degree of freedom (df) less than two is an acceptable fit.[44] Steiger and Lind[45] recommended root mean square error approximation (RMSEA) to evaluate model fit. The RMSEA measures discrepancy per degree of freedom and imposes a penalty for adding complexity to a model without substantially improving model fit. Smaller RMSEA values indicate a better model fit, with values less than 0.05 indicating a close fit. Values between 0.05 and 0.08 correspond to an acceptable fit, and RMSEA values greater than 0.10 suggest a poor fit.[46] The Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) measure the relative reduction in model misfit when comparing the target model relative to a baseline (independence) model. CFI and TLI values ≥ 0.90 have been considered an indication of an acceptable fit of the model to

Table 1

Diarrhea indicator variables grouped into latent variable blocks, Indonesia*

Household hygiene	Environmental quality	Food quality	Drinking water quality
Teeth brushing frequency^{ord}	Number of family members sharing a living space (continuous)	Eating frequency^{ord}	Location of drinking water^{cat}
Hand washing before eating$^{y/n}$	Electricity within the home$^{y/n}$	Purchased meat in previous month$^{y/n}$	Distance to drinking water^{cont}
Hand washing after playing$^{y/n}$	Home ownership status^{cat}	Meat quality^{ord}	Water type^{cat}
Hand washing after toilet use$^{y/n}$	Bathing water is purchased from street vendor^{cat}	Meat price^{cont}	Boiling water prior to drinking$^{y/n}$
Bathing frequency^{ord}	Level of sanitation sharing^{cat}	Milk type consumed^{cat}	Water use for tea, majority^{cat}
House cleaning frequency^{ord}	Wastewater disposal^{cat}	Instant food preparation method^{cat}	Family member responsible for water^{cat}
Milk bottle washing method^{cat}	Garbage disposal method^{cat}	Consumption of vegetable frequency^{ord}	Happiness with water quality^{ord}
Dish washing method^{cat}	Private access to water for washing^{cat}	Street food eating frequency^{ord}	Frequency of use of improved water sources^{cont}
Use of soap frequency^{ord}	Population density in immediate block area^{cont}	Rice preparation method^{cat}	*Escherichia coli* in drinking water^{ord}
Washing water container frequency^{ord}	Home type^{cat}	Government rice subsidy allowance$^{y/n}$	Coliform in drinking water^{ord}
		Cooking fuel type$^{y/n}$	Water storage time from collection^{ord}
		Level of kitchen sharing$^{y/n}$	Water storage container^{ord}
		Own a refrigerator$^{y/n}$	

* ^{ord} = ordinal response; ^{cat} = categorical response; $^{y/n}$ = yes or no response; ^{cont} = continuous response.

the observed data. Our paper uses RMSEA, CFI, and TLI to evaluate the fit of the proposed model. Several models were investigated and the best fitting was selected.

Unlike conventional approaches, SEM groups individual risk factors into risk categories, then models these risk categories against the outcome. In addition, the SEM approach is also preferable because 1) correlated risk categories can be incorporated into the same model (multi-co-linearity is a non-issue), and 2) models elucidate complex pathways involving multiple transmission and mediation routes. For example, regression analysis can show that poverty is a risk factor of diarrhea but SEM is able to show that the poverty–diarrhea link is mediated by poor household hygiene. Because SEM is able to model the complex relationships among risk factors, it is a more realistic interpretation.

Essentially, SEM offers a level of sophistication much needed to understand the complexities of diarrhea risks, and advantageously translates into more informed decision making for designing intervention programs. Against this background, we propose a structural equation model to interpret environmental, socioeconomic, and health data collected form a child cohort. We use this innovative method to analyze childhood diarrhea prevalence in low-income areas of Jakarta, Indonesia.

Ethical clearance. This study was approved by the Secretary of Foreign Research Permits from the Indonesian Ministry of Research and Technology, the Jakarta Governor's Office Department of Population Research Ethics Committee, and the Yale University Human Investigation Committee. Collaboration and verbal consent was provided by community leaders and staff at public child health centers. Oral informed consent was obtained from the legal guardians of all children.

RESULTS

Of the 1,000 children monitored, 257 children had at least one diarrhea episode by our definition. A description of this subset (the group of children who had at least one episode of diarrhea) is shown in Table 2. A slight majority of the children lived in households located in north Jakarta (66%) where the head of household had a high school education (51%), and nearly half (47%) had per-capita incomes below the national poverty line. The mean ± SD age of these children was 31 ± 13 months. The mean longitudinal prevalence of diarrhea for the children who had diarrhea was 25 diarrhea-days per 1,000 child-days, with a wide range (8–158 diarrhea-days per 1,000 child-days). As shown in Figure 1, data are right-tailed, with a Pearson's skewness coefficient of 2.5. Thus, of the children who were sick with diarrhea, most had an acute episode; a minority had persistent or reoccurring diarrhea. The conclusions from factor analysis and the model are community specific.

Exploratory factor analysis. Exploratory factor analysis was used to select the top risk factors for each of the following risk categories: household hygiene practices, environmental quality, food hygiene, and water quality. Principal components with varimax rotation were performed on indicator variables for each risk category. Household hygiene had an eigenvalue of 1.47, and explained 21.02% of the variance in the risk category; environmental quality, with an eigenvalue of 1.98, explained 33.07% of the variance; food hygiene, with an eigenvalue of 1.31, explained 32.78% of the variance; and water quality, with an eigenvalue of 1.89, explained 20.95% of the variance. The four risk categories and their indicator variables, including their factor loading are shown in Table 2. The bivariate correlation among indicators is shown in Table 3.

Values for each risk factor, grouped by the risk category, are shown in Table 2. For continuous response variables, we present the mean and SD, and for categorical variables, we list the frequency and percentage of each value. Covariates, including socioeconomic status and child age, were also considered. The mean and frequency of these covariates also found in Table 2. Approximately half of all children came from families whose household head had not completed high school (49%) and from families that were below the poverty line (47%). Although an equal number of children from north and south Jakarta were surveyed, more than half (66%) of the diarrhea-positive cases (n = 257) were located in north Jakarta. Finally, considering that children who were monitored were all 12–62 months of age at baseline, it should be noted that the average age of those who had diarrhea was 31 months, and the SD was 13 months.

Structural equation modeling. The structural equation model with four risk categories and diarrhea longitudinal prevalence as the outcome was selected to provide a good fit for the data (χ^2 = 214.67, df = 148, χ^2:df ratio = 1.45, CFI = 0.931, RSMEA = 0.042, TLI = 0.90). The model with respective standardized regression weights from each risk category to diarrheal rate is shown in Figure 2. Although errors in highly correlated variables were correlated, these are not shown in Figure 2 for simplification.

In this model, environmental quality (β = 0.097, P = 0.21) and water quality (β = 0.011, P = 0.86) were not found to be significant predictors of diarrhea rate. Instead, food hygiene (β = 0.24, P = 0.008) and household hygiene (β = 0.15, P = 0.094) emerged as significant predictors of longitudinal diarrhea prevalence. The negative regression weights can be interpreted to mean that lower food hygiene and household hygiene were associated with longitudinal diarrhea prevalence. Furthermore, per capita income below poverty (β = 0.44, P < 0.0001) and location (β = 0.032, P = 0.039) were significant predictors of food hygiene, controlling for education and age. With respect to household hygiene, per capita income below poverty (β = 0.16, P = 0038), and age (β = 0.54, P < 0.0001) were significant, controlling for education and location. Per capita income below poverty was the common predictor for decreased food hygiene and household hygiene.

With respect to mediation and pathway analyses, the poverty–diarrhea prevalence link is mediated jointly by household hygiene and food quality. Specifically, households with more severe poverty tend to have poorer household hygiene (β = 0.16, P = 0038) that increased diarrhea prevalence (β = 0.15, P = 0.094); households with more severe poverty also tend to evidence lower food hygiene (β = 0.44, P < 0.0001) that increased diarrhea prevalence (β = 0.24, P = 0.008). With regards to the location–diarrhea link, children living in the north Jakarta (an urban slum) tended to have worst food hygiene (β = 0.032, P = 0.039) compared with those living in south Jakarta (a peri-urban development), and had a higher prevalence of diarrhea (β = 0.24, P = 0.008).

DISCUSSION

In this report, we present an SEM approach to predicting the relative importance of risk categories, including household hygiene, environmental quality, drinking water quality,

TABLE 2

Factor loading for measured variables from latent variables in children 1–4 years of age in Jakarta, Indonesia who had diarrhea during February–July 2011

Variable group	Factor loading	Variable	Population values	Variable shorthand
Covariates		Head of household education		
		Elementary, no. (%)	60 (23)	
		High school, no. (%)	130 (51)	
		Middle school, no. (%)	67 (26)	
		Age in months, mean (±SD)	31 (±13)	
		Located in north Jakarta, no. (%)	170 (66)	
		Per capita earnings below poverty, no. (%)	121 (47)	
Household hygiene indicators	0.642	Teeth brushing frequency		HH1
		Never before, no. (%)	87 (34)	
		Once a day, no. (%)	53 (21)	
		Every time after eating, no. (%)	117 (46)	
	0.556	Washes hands before eating, no. (%)	238 (93)	HH2
	0.491	Washes hands after playing, no. (%)	240 (93)	HH3
	0.481	Milk bottle washing method		HH4
		Sterilizes in boiled water, no. (%)	71 (28)	
		Uses soap and untreated water, no. (%)	68 (27)	
		Rinses with treated (boiled) water, no. (%)	118 (46)	
Environmental quality indicators	0.703	Level of sanitation sharing		EQ1
		Private toilet, no. (%)	166 (65)	
		Shared with neighbors, no. (%)	56 (22)	
		Use of public facility, no. (%)	35 (14)	
	0.619	Wastewater disposal		EQ2
		Public sewer, no. (%)	170 (66)	
		Pit latrine or other underground, no. (%)	27 (9)	
		Directly to surface water, no. (%)	60 (24)	
	0.710	Bathing water is purchased from vendor, no. (%)	67 (26)	EQ3
	0.689	Garbage disposal		EQ4
		Collected by sanitation services, no. (%)	126 (49)	
		Thrown into the river or creek, no. (%)	103 (40)	
		Disposed of in an open trash pit, no. (%)	28 (11)	
Food hygiene indicators	0.628	Street food eating frequency		FQ1
		Daily, no. (%)	183 (71)	
		Often (4–6 times/week), no. (%)	23 (9)	
		Sometimes (1–3 times/week), no. (%)	37 (14)	
		Never, no. (%)	14 (5)	
	0.690	Type of milk consumed		FQ2
		Mother's breast milk, no. (%)	58 (23)	
		Formula, no. (%)	123 (50)	
		Condensed milk, no. (%)	76 (30)	
	0.595	Purchased meat within previous month, no. (%)	59 (23)	FQ3
	0.294	Owns a refrigerator, no. (%)	94 (37)	FQ4
Drinking water quality indicators	0.431	Water Distance, n (±SD)	0.68 (±0.74)	DWQ1
	0.566	Boils water prior to drinking, no. (%)	189 (74)	DWQ2
	0.800	Water type*		DWQ3
		Branded bottled water, no. (%)	30 (11)	
		Refills water from water kiosk, no. (%)	51 (20)	
		Tap water, no. (%)	59 (23)	
		Well water, no. (%)	37 (14)	
		Combination,† no. (%)	80 (31)	
	0.768	Water for tea, majority‡		DWQ4
		Branded bottled water, no. (%)	38 (15)	
		Refills water from water kiosk, no. (%)	63 (25)	
		Tap water, no. (%)	85 (33)	
		Well water, no. (%)	71 (28)	

*Water type is water used for at least 90% of the days monitored.
†Combination describes children who did not use any one type of water more than 90% of the days monitored.
‡Water for tea is based on respondent selection during baseline survey.

and food safety. Household hygiene and food hygiene risk categories were the most significantly linked to diarrhea prevalence. A number of recent studies have begun to investigate the relationship between surface contamination, hygiene, disease transmission, and other factors, such as clean water access and sanitation. More specifically, surfaces were found to harbor significant concentrations of fecal indicators, fomites, and diarrheal pathogens in Tanzanian[47] and Peruvian households.[48] Recently, published evidence has shown that environmental conditions in the household are linked to impaired childhood growth and other indicators of gut enteropathy in rural Bangladesh.[49] Unlike water quality studies, the collection of pathogens from surfaces is not standard practice in the water, hygiene, and sanitation research field, and the importance of household hygiene may have been underestimated in previous research as a result. The survey-based indicators and methods outlined in this report demonstrate the importance of household hygiene without the expensive and cumbersome need to test for pathogens in every home.

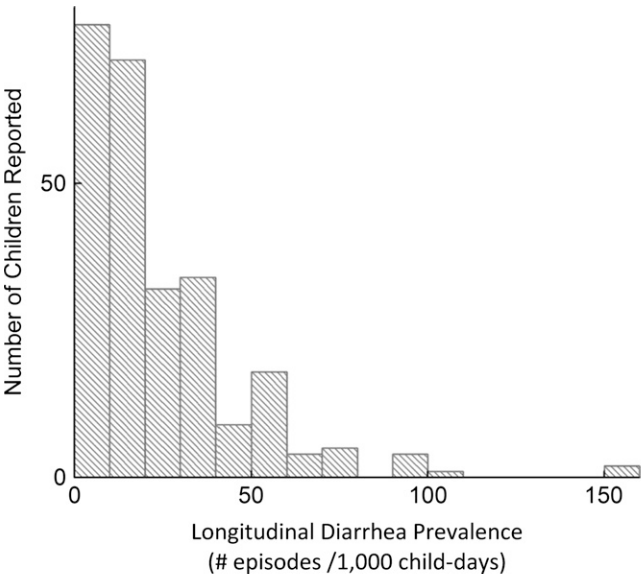

FIGURE 1. Histogram with diarrhea longitudinal prevalence as number of diseased days per 1,000 child-days of follow up shows data for children who had at least one episode of diarrhea. A diarrhea-positive day is defined as a day with two or more loose stools and/or blood and mucus in the stool. Disease days are defined based on caretaker response in weekly logs. Disease numbers are normalized to the number of days of follow-up per child (range = 117–133 days).

The model was able to uncover links between poverty status, geographic location within the city, and hygiene status. The relative importance of disease transmission routes will likely differ in other areas of the world, but the methods outlined in this report are applicable to understand the relative importance of different disease transmission factors with locally relevant data wherever such data may exist.

This report presents an innovative modeling approach that offers distinct advantages. First, unlike multivariable regression, which becomes saturated with many individual risk factors and covariates,[50] SEM is able to group individual risk factors into higher order categories and model these categories with outcome variables. Second, this method accounts for complex interdependent relationships among predictor variables, rather than considering each independent-dependent variable relationship separately. Third, SEM enables mediation and pathway analyses. Fourth, the grouping of individual risk factors into categories lay the groundwork for integrated interventions. For example, SEM enables us to analyze the association between overall household hygiene practices (a risk category) and diarrhea, as opposed to, for instance, focusing only on the association between hand washing to diarrhea. This model can be used to interpret data collected in other areas to improve the global understanding of disease transmission and recommended disease transmission interventions. Similar analyses can be used to understand the infection risks associated with other diseases in crowded slums.

An analytical strategy that is statistically rigorous and able to incorporate complex interactions among various factors can inform holistic intervention strategies, rather than piece-meal solutions. Hygiene education,[13] food safety promotion,[26] community-wide sanitation,[28] and household water treatment,[51,52] have all been recommended to prevent diarrheal infections. Combinations of several interventions are more

TABLE 3
Bivariate correlations among indicators used to predict values for latent variables, Indonesia

Variable	Variable shorthand	Household hygiene				Environmental quality				Food hygiene				Drinking water quality			
		HH1	HH2	HH3	HH4	EQ1	EQ2	EQ3	EQ4	FQ1	FQ2	FQ3	FQ4	DWQ1	DWQ2	DWQ3	DWQ4
Household hygiene	HH1	1															
	HH2	0.206*	1														
	HH3	0.124†	0.344*	1													
	HH4	0.050	−0.004	−0.004	1												
Environmental quality	EQ1	0.043	0.002	−0.178*	0.027	1											
	EQ2	0.043	0.027	−0.068	0.077	0.284*	1										
	EQ3	0.012	0.066	−0.056	−0.099	0.316*	0.361*	1									
	EQ4	0.009	−0.072	0.082	−0.072	−0.273*	−0.219*	−0.295*	1								
Food hygiene	FQ1	0.139†	0.108	0.064	0.122	0.002	−0.068	−0.160†	0.0001	1							
	FQ2	0.159†	0.189*	0.027	0.297*	−0.039	−0.211*	−0.255*	−0.060	0.235†	1						
	FQ3	0.095	0.084	0.071	−0.016	0.040	0.135†	0.266*	−0.062	−0.081	−0.110	1					
	FQ4	0.000	−0.063	0.105	−0.065	−0.290*	−0.262*	−0.157†	0.334*	0.051	−0.006	0.200*	1				
Drinking water quality	DWQ1	−0.044	0.039	0.012	−0.092	0.382*	0.294*	0.410*	−0.282*	−0.199†	−0.217*	0.048	−0.261*	1			
	DWQ2	0.159†	−0.136†	−0.124†	0.002	0.083	0.070	−0.026	−0.012	0.145†	0.018	−0.113	−0.076	−0.080	1		
	DWQ3	−0.011	−0.053	−0.054	−0.033	0.014	0.004	0.005	−0.045	−0.038	−0.030	−0.078	−0.084	−0.009	0.155†	1	
	DWQ4	0.019	−0.191*	−0.015	0.080	−0.091	−0.053	−0.121	0.202†	0.110	−0.076	−0.141†	0.112	−0.123†	0.327*	0.184*	1

*Correlation is significant at the 0.01 level (two-tailed).
†Correlation is significant at the 0.05 level (two-tailed).

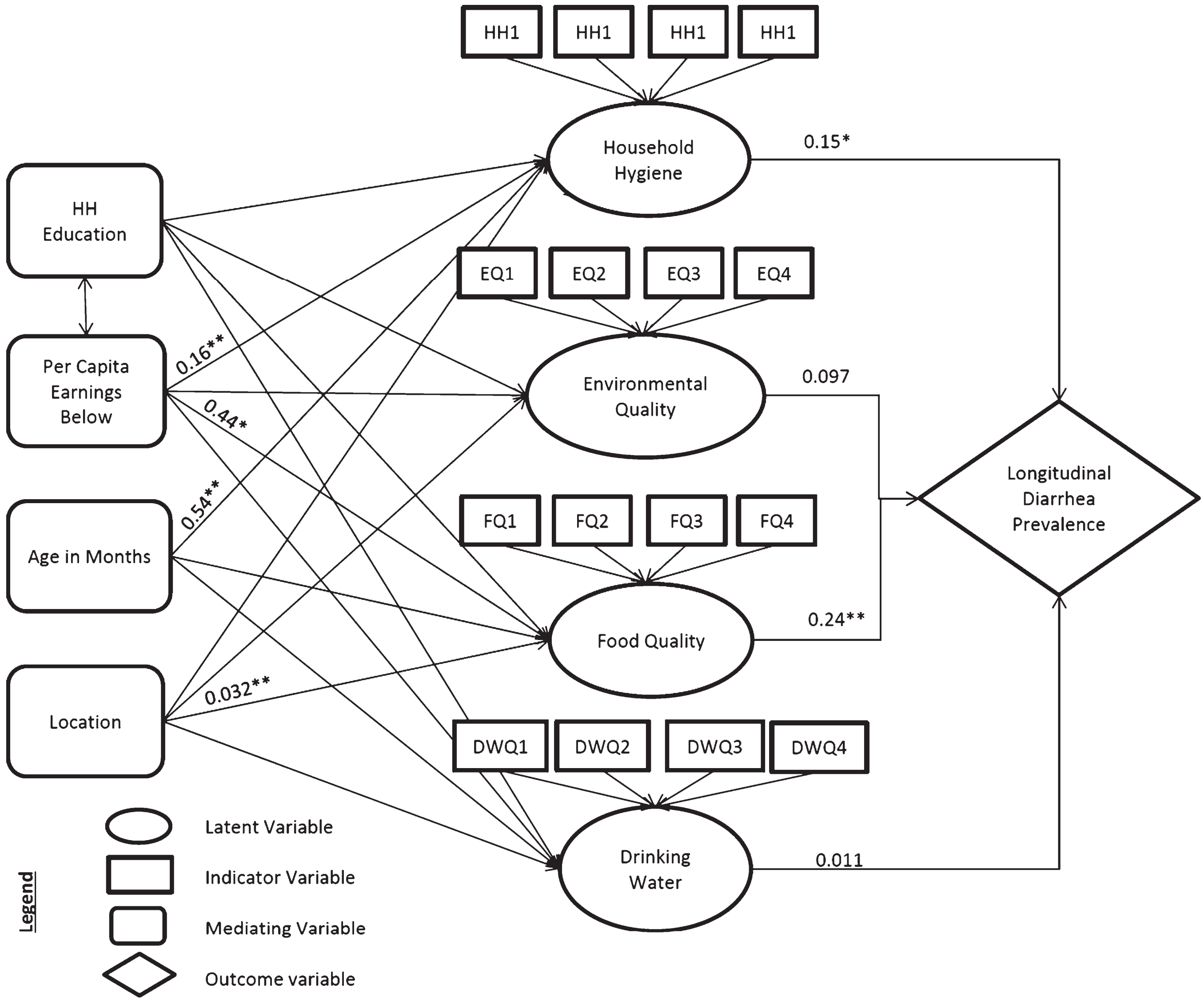

FIGURE 2. Structural equation model of diarrhea describing the relationship between drinking water quality (DWQ), environmental quality EQ), household hygiene (HH), and food hygiene (FQ) indicators (risk categories) and longitudinal diarrhea prevalence (outcome variable). Each risk category is measured by four observed risk factors (refer to Table 2 for a detailed list of the indicators from which these were selected). All error terms and correlations are omitted to simplify the representation. The beta values of relationships estimated using a dataset collected from children less than five years of age in Jakarta, Indonesia, during January–July 2011 is given next to the arrows depicting these relationships. Covariates, such as poverty, location within the city, education of the head of household, and child age are also incorporated into the model. The estimated beta values are shown only for significant relationships. Level of significance is shown by using an asterisk next to the beta values as defined below. * Significant to 0.10; ** Significant to 0.05.

effective than single approaches.[12,27,53] Resources are often limited, especially for urban slum areas, requiring effective intervention approaches to address the most salient risk-factors.[25] By elucidating the relationship among risk categories of diarrhea, this report identifies the most promising intervention types, including those that enhance household hygiene. These findings are similar to those of other groups, whose findings are showing the importance of surface decontamination. Data from a prospective study of childhood diarrhea rates in low-income areas of Jakarta, Indonesia were analyzed by using SEM and analysis showed that food hygiene and household hygiene practices are significantly associated with diarrhea length, controlling for environmental quality and drinking water quality. A possible explanation for this variation may be the length of infections associated with pathogens that are preferentially transmitted by different environmental routes. Findings from other areas confirm that diarrhea length and episode intensity differed by infectious agent in other areas of the world.[54,55] Protozoa, viruses, and bacteria have unique chemical and physical characteristics that may lead them to be preferentially transmitted via different environmental routes. For example, a greater proportion of food-borne pathogens may lead to long diarrhea episodes, and a greater proportion of water-borne pathogens may lead to short-term episodes. The SEM model also enables us to estimate the relationship between covariates and latent predictors, showing that poverty status and location are significant predictors of food hygiene, and poverty status and age in months are significant predictors for household hygiene practices. The model also shows that, as anticipated, household poverty status and head of household education are significantly related.

There are several limitations of this study. First, this is a non-causal model in which all results reflect associations among variables, and no causal relationships among variables can be interpreted from these results. Second, data was collected from a cohort of children that is geographically and socioeconomically specific and results cannot be extrapolated to other population groups. These findings are only pertinent to middle or lower-class children in two areas of Jakarta because children are selected from free health care center records and wealthy children opt out of the public health care system in Jakarta.[39] The data and conclusions are population specific and model specific.

In conclusion, this study presents a useful method for analyzing the complex relationship between various environmental factors, socioeconomic variables, and childhood diarrhea. Using a dataset from Jakarta, we showed that food hygiene and household hygiene are the most significant latent variables associated with longitudinal prevalence of diarrhea among children who had at least one episode of diarrhea. This method is promising and should have wide applicability in the field.

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